(2)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

PORT DOCUMENTATION PAGE

AD-A216 682

1b. RESTRICTIVE MARKINGS

3. DISTRIBUTION/AVAILABILITY OF REPORT
Approved for public release; distribution unlimited.

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)
AFOSR-TR- 89-1771

6a. NAME OF PERFORMING ORGANIZATION
TEXAS A&M UNIVERSITY

6b. OFFICE SYMBOL (If applicable)

7a. NAME OF MONITORING ORGANIZATION
AFOSR

6c. ADDRESS (City, State and ZIP Code)
Mechanical Engineering Department
College Station, TX 77843

7b. ADDRESS (City, State and ZIP Code)
Sumo CO 89

8a. NAME OF FUNDING/SPONSORING ORGANIZATION AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

8b. OFFICE SYMBOL (If applicable)
NA

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
AFOSR 83-0259

8c. ADDRESS (City, State and ZIP Code)
Bld 410
BOLLING AFB DC 20332-6448

10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
61102F	2307	B1	

11. TITLE (Include Security Classification) ROTORDYNAMIC FORCES DEVELOPED BY LABYRINTH SEALS

PERSONAL AUTHOR(S)
GERALD L MORRISON

12. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
FINAL	FROM _____ TO _____	NOVEMBER 1984	7

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

90 01 04 022

DISTRIBUTION/AVAILABILITY OF ABSTRACT

UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS ☐

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
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DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.

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AFOSR-TR- 89-1771

Texas A&M University

Mechanical Engineering Department

Turbomachinery Laboratories

College Station, Texas 77843

"Rotordynamic Forces Developed by Labyrinth Seals"

FINAL REPORT

November 1984

Grant AFOSR-83-0259

Gerald L. Morrison

Prepared for

Air Force Office of Scientific Research

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

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EQUIPMENT PROCUREMENT

The basic laser anemometer system purchased was not the five beam system described in the proposal. The system purchased was recommended by TSI Inc. after the funding was obtained. This system is substantially better that the one originally proposed since it uses three colors for each of the three velocity components instead of two colors and frequency shift. Figure 1 is a schematic of the acquired system. The three color system allows the measurement range of the vertical and on-axis velocity components to be doubled. In addition, the acquired system uses 30° off axis back scatter to collect the doppler signal. This results in a better signal to noise ratio in the photomultiplier output and also yields better spatial filtering by the optic system. The intersection of the three different color measurement volumes was reduced in size using this new system. This was especially important for the measurements inside the labyrinth seals. Attached is a listing of the various parts purchased for both the laser anemometer system and for the computer system dedicated to the laser system.

LASER DOPPLER ANEMOMETER SYSTEM EQUIPMENT
PURCHASED FOR AFOSR EQUIPMENT GRANT

ITEM	QTY	TSI MODEL	DESCRIPTION	COST
1	1	9196-2	2W ARGON LASER WITH BASE	
2	1	9108	BEAM COLLIMATOR	
3	1	9102-11	POLARIZATION ROTATOR FOR CENTER BEAM (488 NM)	
4	1	9102-12	POLARIZATION ROTATOR FOR CENTER BEAM (514 NM)	
5	1	9102-13	POLARIZATION ROTATOR FOR 476.5 NM BEAM	
6	3	9115-1	BEAMSPLITTER	
7	3	9160T	PHOTOMULTIPLIER SYSTEM	
8	3	9140T	RECEIVING ASSEMBLY	
9	1	9145	COLOR SEPARATOR - SCATTERED LIGHT	
10	1	9156	COLOR FILTER	
11	1	9158	COLOR FILTER FOR 514.5 MN WAVELENGTH	
12	1	9159	COLOR FILTER FOR 488 NM WAVELENGTH	
13	1	9180-11	FREQUENCY SHIFT ASSEMBLY FOR 488 NM	
14	1	9180-12T	FREQUENCY SHIFT SYSTEM WITH MIXER	
15	2	9187	BEAM EXPANDER, 8.7X	
16	2	9169-450	LENS, 178 MM FOCAL LENGTH	
17	2	9176	RING MOUNT 4.25" OPTIC AXIS TO BASE	
18	2	9174	BEAM DISPLACER - 25 MM OFFSET TO CENTER	
19	3	9175	BEAM STEERING MODULE	
20	1	9105X	COLOR SEPARATOR - 3 COMPONENT SYSTEM	
21	1	10092	MICROSCOPE OBJECTIVE	
22	1	10096	ALIGNMENT EYEPIECE	
23	1	9193X	BASE FOR 3 COMPONENT SYSTEM	
24	2	9113-16	BEAM SPACER SYSTEM	
25	1	9113-14	BEAM SPACER SYSTEM	
26	3	1990B	COUNTER SYSTEM (INCL. 1995, 1994, & 1991)	
27	1	10097	OPTICS CASE AND ACCESSORIES KIT	
28	1	1992	READOUT MODULE	
29	1	1998	INTERFACE & SOFTWARE	
30	2	1998S	INTERFACE (SLAVE)	
31	1	DRP3	THREE CHANNEL LDV DATA REDUCTION PROGRAM	
			SUB-TOTAL ITEMS 1 - 31	155,681.00
32	1	9500X	TRAVERSE SYSTEM, X-Y-Z AXIS STEPPER MOTOR, TILT, AND SOFTWARE FOR COMPUTER CONTROL	57,760.00
33	1	9180-13	FREQUENCY SHIFT SYSTEM, 476.5 MN	7,220.00
34	2	9306	PARTICLE GENERATOR - 6 JET ATOMIZER	3,300.00
35	3	1988	DIGITAL ANALOG CONVERTER	2,188.00
36	2	1992	READOUT MODULE	3,851.00
37	1	9310	FLUIDIZED BED PARTICLE GENERATOR	8,646.00
			TOTAL, LASER SYSTEM	$238,646.00

COMPUTER SYSTEM PURCHASED AS COST SHARING
FOR LASER ANEMOMETER SYSTEM

ITEM	QTY	DEC MODEL	DESCRIPTION	COST
1	1	11T23-BK	PDP 11/23+ COMPUTER SYSTEM	12,986.00
2	1	MSV11-PL	512KB QBUS MOS MEMORY	1,280.00
3	1	FPF11	FLOATING POINT PROCESSOR	1,280.00
4	1	DLVJ1-LP	4 LINE ASYNC. PORT	559.00
5	1	DRV11-BP	DMA-16 BIT PARALLEL SYS.	636.00
6	1	TSV05-BA	QBUS MAGTAPE SYSTEM & CABINET	8,595.70
7	1	VT125-AA	GRAPHICS CRT	2,675.00
8	1	VT1XX-AB	ADVANCED VIDEO OPTION	125.00
9	1	LA100-ZA	GRAPHICS PRINTER	1,035.00
10	1	QJ013-HH	RT-11 SOFTWARE	1,090.00
11	1	QJ813-HH	FORTRAN 4 FOR RT-11	600.00
12	1	QJ813-DZ	FORTRAN LICENSE	410.00
13	1	QJB56-DZ	GENERAL LICENSE FOR 11/23	512.00
14	1	BC22D-25	NULL MODEM CABLE	48.00
15	2	BC20N-05	NULL MODEM CABLE	100.00
16	2	BC22E-25	EXTENSION CABLE	120.00
17	1	LOT	SHIPPING	600.00
18	1	LOT	HARDWARE INSTALLATION & 90 DAY ON-SITE WARRANTY	N/C
19	1	LOT	INSTALL RT-11 OPERATING SYSTEM	750.00
20	1	LOT	INSTALL FORTRAN SOFTWARE	330.00
			TOTAL FOR COMPUTER SYSTEM	$33,720.10

The procurement of this laser system was delayed for approximately nine months by legal litigation brought about by Disa Electronics. Disa and TSI are the two major manufacturers of laser anemometry systems. The measurement of the flowfield inside labyrinth seals is a very difficult task. It requires that a small measurement volume be obtained and large ranges of velocities with flow reversals be measured. These requirements were pushing the capability of available laser anemometer systems and only the TSI system could perform the task. Disa argued that our statement of measurement capability was to restrictive and then later that they could meet the requirements, however, Disa never produced evidence that they could meet the requirements.

The initial delivery of the TSI system occurred in March 1984 with the final optics arriving in September. Therefore, there have been no measurements made with this system to date. It is anticipated that the system will be operational in the next few months. The computer system is completely operational, the software for controlling the traversing mechanism and for recording data has been installed and is operational. The traversing system is also operational.

EQUIPMENT USAGE

The laser anemometer system was purchased for measuring the flowfield inside labyrinth seals. This objective is being pursued in conjunction with AFOSRIAF Contract No. F49670-0033. This contract has paid the salary of a graduate student who has been responsible for setting up the laser system and designing the labyrinth seal test section. In order to evaluate the performance of the laser system, the flow in a suddenly expanded pipe is to be measured first. In this well documented flow, the ability of the laser system to measure flow reversals and high turbulence levels can be determined. In addition, the type of seed particles and seed injection rate will be studied to determine the appropriate conditions to use for the labyrinth seal flowfield measurements. As soon as the laser is ready for measurements, the suddenly expanded pipe flow measurements will be performed. The design for the labyrinth seal to be tested is also nearing completion.

Work has also been undertaken to develop the software necessary to calculate the turbulence dissipation rate. Software has been written that allows us to access the encoded data files generated by the software purchased from TSI which controls the traverse system, records raw data and reduces data. This was necessary since the TSI software does not calculate turbulence dissipation rates, spectra, or correlations. All of these quantities will be needed in the study of the turbulence inside the labyrinth seal. This information is required to help develop advanced turbulence models.

Additional proposals have been sent to AFOSR and NSF to

study coherent structures in high speed jets. The purpose of these studies is to gain a better understanding of turbulence in free shear flows and how large scale coherent structures interact with the small scale turbulence to govern the development of the jet flowfield. These proposals included the use of a second laser anemometer system for use in ensemble average measurements.